Before the
Federal Communications Commission
Washington, DC 20554

In the Matter of	)	
	)	
Facilitating Opportunities for Flexible, Efficient, and Reliable Spectrum Use Employing Cognitive Radio Technologies	)))	ET Docket No. 03-108

To: The Commission

COMMENTS

CINGULAR WIRELESS LLC

J. R. Carbonell
Carol L. Tacker
David G. Richards
5565 Glenridge Connector
Suite 1700
Atlanta, GA 30342

BELLSOUTH CORPORATION

James G. Harralson
Charles P. Featherstun
1155 Peachtree St., N.E.
Suite 1800
Atlanta, GA 30309
(404) 249-3855

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SUMMARY

Cognitive radio technology is a useful tool when employed in conjunction with other spectrum management tools. A licensee can employ it internally to manage its network more efficiently and intensively. Cellular and PCS networks have always depended integrally on cognitive radio technologies to achieve higher capacity, better quality, and more extensive coverage. Licensees of exclusive spectrum blocks have an incentive to employ these techniques, when cost-justified, in order to optimize the use of their licensed spectrum and provide new services to their customers.

A licensee may be able to take advantage of cognitive radio technology to facilitate sharing or leasing of its spectrum in a secondary market transaction with third parties. The licensee would be able to design and operate its network while continuing to maintain full control of the RF environment, because any usage of its spectrum by others would be on the licensee's terms. The Commission need not adopt any rules to give licensees an incentive to use cognitive radio in this manner.

These benefits would be put at significant risk, however, if the Commission were to use cognitive radio technology as a way of forcing licensees to share their spectrum with unlicensed third parties. Requiring a licensee to endure a non-licensee's use of the licensee's spectrum on an opportunistic basis with cognitive radios would disrupt the licensee's internal management of its radio network. Such a requirement would also adversely impact the leasing of spectrum in the secondary market. A licensee needs to control how its spectrum is used. Otherwise, "rogue" devices have the potential to cause interference that will reduce efficiency by degrading quality, capacity, and coverage. Eventually, licensed networks would need to employ higher power for both mobiles and base stations and add cell sites to avoid the loss of coverage.

Licensees would not introduce new, efficient technologies if the efficiency gains could be wiped out by unlicensed use of their spectrum. Moreover, the Commission's suggestion that the use of cognitive radios will avoid interference problems is entirely premature, given that no cognitive radios designed to coexist autonomously with licensed services exist. There are significant issues to be addressed before such usage can be allowed.

If the Commission proceeds further with this issue, it should perform a detailed cost-benefit analysis. Given the lack of real-world experience showing that unlicensed sharing with licensed services via cognitive radio is feasible, and the considerable spectrum already available for unlicensed use, there is no rational basis for affording unlicensed cognitive devices access to CMRS spectrum.

The use of cognitive radio technology *within* unlicensed spectrum, in accordance with standards established by industry groups or the Commission, could facilitate more efficient use of the spectrum in those bands, particularly in rural areas. When confined to unlicensed spectrum, the introduction of cognitive radios would tend to diminish interference and improve efficiency. Some such radios already have been introduced, like the multi-band/multi-standard 802.11a/b/g Wi-Fi devices, and such devices may allow more intensive use of unlicensed bands with less interference.

Cingular and BellSouth also address numerous detailed technical questions posed in the *NPRM.*

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COMMENTS

Cingular Wireless LLC ("Cingular") and BellSouth Corporation ("BellSouth") (hereinafter referred to as "Joint Commenters"), hereby submit their comments in response to the Commission's *Notice of Proposed Rulemaking* concerning cognitive radio technologies.[1]

Cingular and BellSouth have long supported the use of increasingly sophisticated technology, such as software-defined radio ("SDR") and what is now known as cognitive radio, in the interest of increasing spectrum efficiency.[2] Accordingly, Joint Commenters agree with the Commission that the use of cognitive radios has the potential to improve spectrum access and efficiency of spectrum use in appropriate circumstances. Cognitive radio technology is not,

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1 *Facilitating Opportunities for Flexible, Efficient, and Reliable Spectrum Use Employing Cognitive Radio Technologies,* ET Docket 03-108, *Notice of Proposed Rulemaking and Order,* ET Docket 03-108, 18 F.C.C.R. 26859 (2003) (*NPRM*), *summarized,* 69 Fed. Reg. 7397 (Feb. 17, 2004).

2 *See* Comments of Cingular, *Software Defined Radio,* ET Docket 00-47 (filed March 19, 2001) ("Cingular SDR Comments"); *see also* SBC Wireless Comments, ET Docket 00-47 (June 14, 2000); BellSouth Corporation Comments, ET Docket 00-47 (June 14, 2000).

however, a panacea that can be employed in any situation with beneficial results; it does not solve all of the difficult issues of spectrum management, as the *NPRM* appears to suggest.[3]

DISCUSSION

I. COGNITIVE RADIO CAN BE A BENEFICIAL TOOL WHEN EMPLOYED BY A LICENSEE FOR INTERNAL USE OR FOR VOLUNTARILY SHARING USE OF ITS SPECTRUM, BUT HAS SIGNIFICANT DETRIMENTS WHEN USED TO IMPOSE SPECTRUM SHARING ON LICENSEES INVOLUNTARILY

Cognitive radio technology is a useful tool when employed in conjunction with other spectrum management tools by the party responsible for the use of a given band of spectrum. Thus, cognitive radio technology can be useful to a licensee as one of the tools used internally to manage its licensed network by allowing a given quantity of spectrum to be used more efficiently and intensively, thereby resulting in higher capacity, better quality, and more extensive coverage. Moreover, the licensee may be able to take advantage of cognitive radio technology to facilitate sharing or leasing of its spectrum in a secondary market transaction with third parties. In addition, cognitive radio technology could be used, in accordance with standards established by industry groups or the Commission, to facilitate more efficient use of the spectrum in unlicensed bands, particularly in rural areas.

These benefits would be put at significant risk, however, if the Commission were to use cognitive radio technology as a way of forcing licensees to share their spectrum with unlicensed third parties. Allowing non-licensees to use a licensee's spectrum on an opportunistic basis with cognitive radios by regulatory fiat would disrupt the licensee's own internal management of its radio network, potentially upsetting the spectrum efficiency benefits the licensee has already de-

3 While these comments focus primarily on the CMRS bands, the same concerns and considerations apply to other non-CMRS licensed bands such as Multi-channel Multipoint Distribution Service ("MMDS") and Wireless Communications Service ("WCS").

rived from its own use of a carefully managed cognitive radio technology and making it much more difficult, if not impossible, to lease the use of the spectrum to others in the secondary market.

A. Benefits of Cognitive Radio When Employed Internally by a Licensee

The commercial cellular and PCS industry has in the past and will continue in the future to develop and deploy technology and techniques like cognitive radio technology when performance and cost makes it attractive to do so. As the Commission recognizes, various forms of cognitive radio technology are already in use.[4] In fact, cellular and PCS systems have always depended integrally on cognitive radio technologies (*e.g.,* dynamic power control and frequency selection based on real-time measurement of the radio frequency environment, adaptive modulation and coding schemes, protocols for data collision avoidance, error detection and correction, interaction with other devices) that have been at the core of cellular network design from the very start.[5]

As Cingular mentioned in the SDR proceeding, the primary benefit of this type of technology is that it can permit more efficient deployment and implementation of equipment.[6] The cognitive functions employed could include frequency agility, adaptive modulation, transmit power control, detailed control protocols, and various security features. Licensees of exclusive spectrum blocks have an incentive to employ these techniques, when cost-justified, in order to optimize the use of their licensed spectrum and provide new services to their customers. The use of these techniques in a commercially operated and licensed network is simply a matter of con-

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4 *NPRM* at ¶ 11.

5 *See, e.g.,* Z.C. Fluhr and P.T. Porter, *Advanced Mobile Phone Service: Control Architecture,* 58 BELL SYS. TECH. J. 43, 47-68 (1979).

6 *See* Cingular SDR Comments at 1-2, 8-11.

trolling the network's design and operation so as to maximize its utility. Licensees will only have an incentive to use these techniques if they have control over the spectrum in which they operate. In that way, they know what can be introduced in their licensed band in order to use the spectrum most efficiently, given the multiple variables (*e.g.*, capacity, power levels, device density) present in offering quality service to customers. Without complete control over the RF environment in their licensed spectrum, licensees will not be incented to optimize their networks for efficient spectrum usage, but will instead be incented, first and foremost, to ensure that their customers' communications are not disrupted by external sources of interference — which may mean foregoing efficiency in the interest of robustness.

B. Benefits of Cognitive Radio for Voluntary Secondary Market Applications (Leases, Easements)

Similar to employing cognitive radio technologies internally, licensees may see opportunities to lease all or part of their spectrum to third parties who employ cognitive radio capabilities. The parameters of this arrangement would be spelled out contractually, including the means to be used to protect the licensee from interference and under what conditions (if any) the licensee retains the ability to interrupt the third party's use. The contract and related documents would, therefore, enumerate the specific technical protocols that the third party would be expected to follow. These might include technologies already used in cellular or PCS systems, as well as other techniques. The licensee would be able to design and operate its network while continuing to maintain full control of the RF environment, because any usage of its spectrum by others would be on the licensee's terms.

A licensee considering such arrangements will base its decision on whether the spectrum could be used efficiently by the third party without causing an unacceptable degree of interference to the licensees' operations. Through the terms of the contract, the licensee would determine the type of interference, if any, that the lessee could cause, and the licensee would then be in a position to manage the effects of that interference through its own network design and operational parameters. Thus, the licensee would be able to balance the cost of managing such interference against the increased economic utility of the license resulting from the lease. Critically, the licensee would retain control of its licensed spectrum so that it can ensure the quality of service that it is providing to its customers.

The Commission does not have to adopt any rules or standards concerning cognitive radios to give licensees an incentive to incorporate such technologies into leasing and other voluntary secondary market arrangements. If the use of cognitive radio technology will enable a third party to derive sufficient value from leased spectrum that outweighs the costs imposed on the licensee, the licensee has an economic incentive to enter into a leasing agreement. The adoption of rules will not make such arrangements any more feasible or economically justifiable; the only effect of such rules would be to skew licensees' market-based incentives.

C. Cognitive Radio Should Not Be a Basis for Involuntary Access to Licensed Spectrum by Unlicensed Third Parties

1. Unlicensed Sharing of Licensed CMRS Spectrum via Cognitive Radios Is Contrary to the Public Interest

Allowing third party access to exclusively-licensed spectrum based on such party's use of cognitive radio technology will actually give licensed operators a disincentive to employ cognitive radio themselves and to enter into voluntary leases that rely on cognitive radio. This forced leasing would lead to less efficient spectrum use by licensees and diminish the spectrum efficiency that the Commission sought to foster by permitting secondary market spectrum transactions.

A cellular or PCS licensee needs to control how and when spectrum is used in its licensed area. Otherwise, devices not under the licensee's direct or indirect control — "rogue" devices —

have the potential to cause problems. Their interference (whether or not it reaches the level deemed "harmful") will reduce the network's efficiency by degrading quality, reducing capacity, and diminishing coverage[7]. Given the protocols already employed by cellular and PCS networks, the introduction of uncontrolled transmitting devices into a licensee's spectrum and coverage area will automatically result in the use of increased power to overcome the increased interference and noise level in the short term. If such rogue devices become commonplace, networks will have to be designed defensively to protect against the increasing likelihood of destructive interference. Designing networks to protect against such interference means that networks will have to become less reliant on low mobile device transmit power, employing higher signal levels to overcome the effects of an increased interference and noise level. Networks will become more expensive, due to the need for more cell sites and redundant coverage to avoid the loss of service to some areas (*e.g.,* at the outer boundaries of cells or inside buildings or parking garages, where mobile units operate at or near their maximum power levels today and would not be able to increase power to contend with new sources of interference). As V-Comm has shown in its comments, the cost of reengineering cellular and PCS networks to accommodate even a small increase in the interference and noise floor due to the presence of opportunistic unlicensed devices would be massive.[8]

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[7] Similar to questions raised in the Interference Temperature proceeding, if interference is experienced in the licensed band and there is an unlicensed underlay, the unlicensed device must cease operation based on Part 15 rules. However, would the licensee be required to track down the interferor? How would the FCC enforce this interference management?

[8] See Comments of V-Comm, L.L.C., at § VI, *Network Impact Study* (filed in ET Docket on 03-237 April 5, 2004; filed in ET Docket 03-108 on April 27, 2004).

As the FCC notes, licensees employ technologies in their networks that are increasingly complex and efficient, including cognitive radio technologies.[9] However, some of the innovations that have made this possible would never have been relied upon if the Commission had allowed unlicensed use within the CMRS bands. For example, the low transmit power levels of today's digital phones, which allow the use of smaller batteries with longer life, would not have been possible had licensees been faced with the ubiquitous use of their spectrum by unlicensed devices, *whether or not those unlicensed devices incorporate cognitive radio technologies.*

Throughout the *NPRM,* the Commission suggests that unlicensed use of licensed bands will be no problem as long as cognitive radios are used. It is entirely premature, however, to assume that there will be no problems, given that no cognitive radios designed to coexist autonomously (*i.e.,* not under central control) with spectrum-intensive services such as cellular and PCS yet exist, nor, as some would contend, is it possible[10]. The fact that innovative technologies are under development for use by the military under coordinated battlefield conditions,[11] for example, does not mean that those technologies will be usable in the highly managed RF environment of a cellular or PCS network.

In fact, there are significant technical issues to be explored before this type of operation can be allowed. The Commission assumes that devices can determine that spectrum is not in use. This is a conclusion based on limited scenarios that may not be applicable to broader cases. Successes to date have been based on time division duplex ("TDD") technologies, where the same frequency is used for up- and down-links, thereby simplifying identification of affected

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9 *See NPRM* at ¶¶ 1, 3, 11.

10 See Comments of Proxim Corporation, *Interference Temperature,* ET Docket 03-237, at 2 (April 5, 2004).

11 *See NPRM* at ¶ 16.

transceivers.[12] There has been little or no successful experimentation with this type of operation in the context of mobile CMRS systems based on frequency division duplex ("FDD") operations, which use different frequencies for the up- and down-links.

FDD poses a particular difficulty for autonomous cognitive radios because the unit's evaluation of the signal/noise/interference level on a given frequency will not indicate whether transmitting on that frequency will cause interference to a unit at an unknown location that only *receives* on that frequency, but transmits on a different frequency. If a base station transmits on frequency X and the mobile transmits on frequency Y, a cognitive radio would not be able to determine whether it is safe to transmit on either frequency simply by listening for "unused" spectrum. Spectrum that appears to be vacant may in fact be one half of a paired channel that is in use. A signal transmitted by an unlicensed device on the supposedly vacant frequency could reach a sensitive receiver; this signal could have numerous adverse effects, such as frame errors, loss of synchronization, packet retransmission, or loss of the desired signal.

The fact that multiple autonomous TDD networks, such as 802.11 local area networks, can coexist successfully in many cases does not mean that such networks can coexist with FDD networks, especially those using entirely different protocols. The 802.11 standards include a Carrier Sense Multiple Access/Collision Avoidance ("CSMA/CA") media access protocol to avoid interference among 802.11 units. This includes a form of "listen-before-talk" protocol, in that devices transmit only when they believe a channel to be vacant, but the CSMA/CA protocol also provides for acknowledgements, given that the transmitting device cannot know whether

[12] For example, IEEE 802.11 local area "Wi-Fi" networks are TDD-based. Moreover, the Commission's rules for unlicensed PCS and unlicensed National Information Infrastructure operations are premised on TDD. *See* 47 C.F.R. § 15.301-.323 (unlicensed PCS), 15.401-.407 (U-NII).

another device may attempt to communicate at the same time, causing a signal collision. Moreover, even this procedure can break down when there are multiple "hidden nodes" that cannot sense each others' signals, but that are both sending signals that are detected by a common device within range of both, and further problems are caused when the devices are operating outdoors over a significant distance.[13] These problems will be compounded greatly if 802.11 devices were to operate on spectrum used by licensed networks in FDD mode. The 802.11 devices will be listening for signals on the channels that they are designed to use, not the paired frequencies used by the FDD networks, and the licensed networks would not be providing responses that could be used intelligently by the 802.11 devices. Furthermore, problems will be exacerbated as the density of users increases. The reduction in effectiveness of 802.11 operations, for example in congested situations, is well known as a by-product of non-coordinated ad hoc operation of unrelated transmitting devices.

When multiple 802.11 networks are deployed in the same geographic area, the individual networks are typically assigned to operate on different channels, thus avoiding co-channel interference whenever possible. As more unlicensed networks are added in a given area, it becomes increasingly difficult to avoid interference through separate channel assignments and the network's performance may degrade. This, of course, suggests that if cognitive radios have all of the benefits that the Commission believes, they should be able to continue to provide increasing capacity and avoid interference in the bands where they are currently allowed (*i.e.,* the unlicensed bands). Thus the promises of cognitive radios for unlicensed devices should be developed and deployed to increase the capacity of the existing unlicensed bands.

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[13] *See generally* Alberto Escudero-Pascual, *WLAN (IEEE 802.11B) and WMAN (802.16A) Broadband Wireless Access: When Opportunities Drive Solutions,* <http://www.it.kth.se/~aep/publications/2003/escuderoa-80211-bwa.pdf>.

The main focus of the Commission with respect to licensed operations, should be on the prevention of interference. The Commission's spectrum management responsibilities comprise multiple objectives, including interference prevention, allocation of spectrum to meet demand consistent with the public interest, and promotion of efficient spectrum use. Allowing unlicensed access to licensed CMRS, MMDS, and WCS spectrum through the use of cognitive radio technologies will further none of these objectives. Interference to licensed systems will inevitably be increased, not prevented. Spectrum needed to meet the demand of customers in these services would effectively be de-allocated and the overall efficiency of the spectrum usage would be reduced. The fact that a sophisticated radio (and, therefore, presumably an "efficient" one) is used by the unlicensed user does not make the shared use of licensed spectrum a more efficient use of spectrum, given that it will impose significant inefficiencies on the licensed user and its customers.

In the event the Commission decides to proceed further down this path, it should perform a detailed, quantitative cost-benefit analysis. From an economic perspective, the important issue is whether the net benefits of unlicensed/licensed sharing based on cognitive radio are greater than any associated costs. Here, the benefits are largely speculative — there has been no quantification of benefits. Indeed, it is unclear what applications are expected to be filled by unlicensed devices using cognitive radio technologies. Yet, the costs are fairly well known, if not fully quantified. Unlicensed sharing of the CMRS bands would have a direct impact on the 150 million subscribers of CMRS as well as the substantial investment by CMRS providers. Public-good benefits of CMRS would also be put at risk, including increased productivity from using these products, improved communications, availability of wireless broadband services, services to rural areas, and public safety benefits. As such, even a relatively small service degradation can carry large adverse consequences. Therefore, cognitive-radio-based sharing poses an economic tradeoff between known goods and services, highly valued by the consumers and producers who utilize them, and a speculative set of goods and services, whose identity is unknown and whose economic value and successful realization are unknown.

Moreover, there is no real-world experience demonstrating that unlicensed sharing of licensed CMRS spectrum via cognitive radio is even feasible. There are claims that devices can be manufactured to sense the usage of a given block of spectrum and decide what frequencies to use, but there has been no supporting information adduced to show that this approach is economically practicable in CMRS bands, much less that such operations can avoid all interference with licensed operations. Given the considerable amount of spectrum (more than 700 MHz) that has already been allocated for unlicensed operations,[14] and the minimal use that has been made of some of these allocations,[15] the Commission lacks a rational basis on which to give unlicensed devices access to some of the most intensively used spectrum around.

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14 This includes the 902-928 MHz ISM band, the 1910-1920 MHz and 2390-2400 MHz bands for asynchronous unlicensed PCS, the 1920-1930 MHz isochronous unlicensed PCS band, the 2400-2483.5 MHz ISM band, and the 5 GHz U-NII bands (5.15-5.35 GHz and 5.47-5.875 GHz).

15 For example, the unlicensed PCS spectrum allocated in 1994-95 for, among other things, wireless local area networks has gone largely unused. *See* Comments of the Consumer Electronics Association, ET Docket 03-201, *Modification of Parts 2 and 15 of the Commission's Rules for Unlicensed Devices and Equipment Approval,* at 11 (Jan. 23, 2004) ("The UPCS bands consist of the highly desirable spectrum ranges of 1910-1930 and 2390-2400 MHz, yet today these bands are comparatively vacant. As the Commission itself has noted in its consideration of petitions to change the UPCS etiquettes or to reallocate this valuable spectrum, there is little use of these bands despite their prime location.") (*citing Advanced Wireless Services,* ET Docket 00-258, *Memorandum Opinion and Order and Further Notice of Proposed Rulemaking,* 16 F.C.C.R. 16043 (2001), *Second Report and Order,* 17 F.C.C.R. 23193 (2002); *Third Notice of Proposed Rulemaking,* 18 F.C.C.R. 2223 (2003)).

2. Dynamic Frequency Selection

In paragraph 24 of the *NPRM,* the Commission discusses the use of DFS, which it describes as "a mechanism that selects an appropriate operating frequency for a device based on some specific condition."[16] In the *Interference Temperature* docket, Joint Commenters have already addressed the difficulties posed by having a cognitive radio attempt to determine whether it may transmit without interference to licensed devices. The principal difficulty, in the context of a CMRS network with many base stations and an even greater number of mobile units at unknown locations, is determining the level of signal that would cause interference at any given receiver location.[17] The cognitive radio can determine received power levels at its own location, but not at the locations of the various receivers. This is especially difficult in the context of CMRS networks, which use FDD, because the signal a cognitive radio receives from a given licensed location tells the cognitive radio nothing about the level of signal at its intended receive site. The cognitive radio concept is more suited to an environment where the transmitter and receiver for a given frequency are at a single common location, *e.g.,* for systems that are based on TDD. The Commission has recognized this through its 5 GHz U-NII band rules for sharing of spectrum between unlicensed devices and Government systems (*i.e.,* a "monostatic environment" as is generally the case with radar systems).

Moreover, DFS by unlicensed devices could disrupt the frequency reuse patterns on which licensed CMRS networks are premised. CMRS operators rely heavily on careful planning of frequency reuse patterns as a method of interference avoidance, ensuring that co-channel frequencies are sufficiently separated to achieve acceptable levels of interference in the system

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16 *NPRM* at ¶ 24.

17 *See* Comments of Cingular and BellSouth, ET Docket 03-237, at 25-26 (filed April 5, 2004) ("Cingular/BellSouth IXTemp Comments").

while simultaneously maximizing the capacity of the system. If cognitive radios were to degrade the frequency reuse factor it could seriously erode capacity to support users and/or quality of service. Moreover, many carriers have implemented their own cognitive radio capabilities in their networks such that frequency planning is done on a more real-time basis tied to network loading. Cognitive radios that have not been designed as an integral part of the system operation may or may not operate correctly in terms of interference avoidance and may cause severe interference to the licensed system.

In the context of DFS, the Commission also discusses the possibility of using dynamic polarization selection. It is questionable whether this is practical, given that in a CMRS network, handheld units will have somewhat random antenna orientation and multipath interference tends to alter the polarization of signals.[18] In terms of measuring the use of a certain band of spectrum, cognitive radios should be required to sense orthogonal polarizations and multiple directions of propagation to ensure that an accurate measure of the RF environment is obtained.

3. Transmitter Power Control

In paragraph 27, the *NPRM* discusses the use of Transmitter Power Control ("TPC") by cognitive radios, similar to its use in numerous existing radio systems. Merely defining a TPC method in the standards or rules for a given radio service or class of unlicensed devices does not ensure that TPC is in fact used effectively. If TPC operation is not *required* in the governing protocol of the radio, and is not *certified* to operate as required, then the devices in question may not use TPC in an effective manner to prevent interference. For example, Wi-Fi access points could lower their power in accordance with the IEEE 802.11 standards' TPC protocols, but do

[18] *See Year 2000 Biennial Regulatory Review — Amendment of Part 22 of the Commission's Rules to Modify or Eliminate Outdated Rules Affecting the Cellular Radiotelephone Service and other Commercial Mobile Radio Services,* WT Docket 01-108, *Report and Order,* 17 F.C.C.R. 18401, ¶ 48 (2002).

not do so. As a result, when one device interferes with another, both devices may end up actually increasing power to overcome the interference. When a network of devices is not under centralized control, the only control is that which is *required* by the design standard to which the network adheres. If the standard does not require TPC in accordance with a detailed protocol of power correction responses to particular inputs, the fact that the standard includes TPC provides no assurance that it will be used effectively in practice.

4. Specialized Detectors

In paragraph 25, the *NPRM* discusses the possible use of specialized detectors that can sense very low-level signals, including signals below the noise floor. The Commission notes such specialized detectors "use longer sensing times and internal computation to achieve signal sensitivities below the noise level for signals of known format," achieving a processing gain of up to 30-40 dB.[19] These detectors are not practicable for cognitive radios sharing spectrum with licensed CMRS operations, however, because of the longer sensing times involved (as much as several seconds). In CMRS, licensed transmitters vary their transmitting power up to hundreds of times per second, and in some access technologies (such as GSM), hop frequencies many times per second as well. A detector would have to act much faster than the frequency and

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19 *NPRM* at ¶ 25. Apparently, these detectors are designed specifically to take into account the characteristics of a known signal format in reaching their high levels of sensitivity. The Commission does not address what happens when signals do not follow the known format on which they are premised. Given that the Commission's rules do not establish mandatory signal formats for digital CMRS, and signal formats may therefore be changed over time, reliance on specialized detectors designed for one or more specifically defined signal formats would be inappropriate, even if the measurement time were not an issue.

power changes in the service at issue, making these specialized detectors inappropriate for CMRS spectrum sharing.[20] Moreover, who would pay for, maintain and operate these detectors?

5. Adaptive Modulation Techniques

In paragraph 26, the *NPRM* discusses the use of "adaptive modulation techniques" that can choose waveforms to work around other signals that are present. While the Commission's description of adaptive modulation techniques is generally correct, it does not appear to be relevant to unlicensed sharing of licensed spectrum. Adaptive modulation techniques are typically used to choose the modulation and error correction coding to be used on the link with the target device, usually referred to as link adaptation. For example, a cellular or PCS handset might be capable of operating in two different digital modes, such as GSM and TDMA or iDEN and GSM, automatically selecting the mode that is used by the network at hand.[21] Adaptive modulation is also used to extend the range of cells. Increases in the noise plus interference floor due to the use of unlicensed underlays would nullify the coverage improvements, making some cell site construction cost-prohibitive.

These devices have not generally been designed to choose modulation techniques based on the presence of other signals from devices with which the unit will *not* be communicating, except perhaps to avoid interference *from* those other devices. Thus, if other signals (*e.g.,* from a licensed network) are on the same frequency or nearby frequencies, the link adaptation will typically move to a lower-order modulation and/or a more robust coding scheme to avoid being in-

[20] Accordingly, whether or not such detectors would be capable under other circumstances of mitigating the "hidden node problem," *see id.* & n.35, their impracticality in CMRS leaves the hidden node problem unresolved.

[21] *See, e.g., NPRM* at ¶ 26 (" For example, [a cognitive radio] could switch between different channel access schemes such as time division multiple access (TDMA) and code division multiple access (CDMA) depending on the type of system in use.")

terfered with, rather than using the modulation scheme of the other signals. An unlicensed wireless LAN device using cellular or PCS spectrum would not switch to CDMA or GSM modulation schemes depending on the CMRS signal received; it would simply use a modulation or coding technique intended to lessen interruptions from the CMRS signal.

Moreover, the signal from the unlicensed device will increase the noise and interference floor of the licensed network. If the devices in the licensed network are designed with link adaptation features, the licensed network may be able to maintain communications, but at the cost of capacity given up to maintain robustness. In this case, the total information-carrying capacity of the *licensed* link has been diminished; fewer net bits of information are transferred across the link. This will reduce the voice quality and data speed available on the licensed network, as well as the system's coverage. While the licensed link may still be operational due to link adaptation, the network's capacity has been reduced because less end-user information (voice or data) can be transferred. Even though the licensed network's use of link adaptation means that its transmissions are not completely cut off due to unlicensed sharing, there still is harmful interference because the licensed carrier loses capacity that it would have had but for the unlicensed operation.

II. COGNITIVE RADIO TECHNOLOGIES MAY BE USEFUL IN UNLICENSED BANDS

The use of cognitive radio technologies may be very useful in bands designated for unlicensed use. As mentioned previously, such technologies could relieve some of the congestion that occurs in these bands due to the lack of centralized control over interference.

In particular, autonomous cognitive radios should be confined to operation within bands that are specifically allocated to unlicensed use. As discussed in the preceding section, autonomous cognitive radios do not mix well with centrally-managed licensed CMRS networks. Given the autonomous nature of unlicensed use, however, the introduction of cognitive radios into the unlicensed bands would tend to diminish interference within those bands and improve the efficiency of unlicensed spectrum usage.

Some steps have already been taken in this direction without any FCC prodding. For example, there are multimode 802.11 devices that can operate in accordance with both the 802.11a and the 802.11g standards — and the latter standard includes a fallback to 802.11b as well. Thus, a laptop computer equipped with an 802.11a/g adapter can negotiate the most favorable wireless connection with a given access point, altering the frequency, modulation, and data rate to be used based on the technology available within that access point and the surrounding RF environment.

Unlicensed devices using a variety of technologies share these bands. For example, the 2.4 GHz band is used by cordless telephones employing a variety of protocols, wireless local area networks ("WLANs") employing 802.11a, 802.11g, and HomeRF protocols, and other devices such as Bluetooth radios. In many cases, these technologies are not mutually compatible. As a result, there have been instances of interference between wireless LANs and cordless phones, and between wireless LANs and Bluetooth, for example. The HomeRF standard was an attempt to avoid such interference, but it was quickly supplanted by the 802.11 Wi-Fi standard for WLANs, and the HomeRF Working Group has been disbanded.[22] The introduction of cognitive radio features to future wireless products using this band could allow more intensive use of the band with less interference.

Given the potential of unlicensed devices to interfere with licensed operations in the same band, and the untried nature of the cognitive radio technologies proposed for unlicensed opera-

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22 *See* Richard Shim, *HomeRF Working Group Disbands,* C|Net News.Com, <http://news.com.com/2100-1033-979611.html>.

tions, the public interest would be better served by encouraging the use of such technologies in the bands already allocated for unlicensed operations. Such technologies are unlikely to degrade the quality of service in these allegedly interference laden bands, and may actually improve unlicensed devices' ability to coexist with each other.[23]

III. TECHNICAL RESPONSE TO THE *NPRM*

It is highly questionable whether cognitive radio technology would actually be capable of gauging licensed CMRS usage sufficiently to determine the existence of temporarily available spectrum and then use it in a manner that does not pose an interference threat to licensed operations. Moreover, the widely distributed use of such radios even in such fleeting "white spaces" within a CMRS network would necessarily increase the noise and interference floor that the CMRS network is engineered for, with adverse consequences to licensed CMRS operations and consumers who depend on them.

Nevertheless, the Commission has placed numerous issues on the table for comment. Joint Commenters' comments regarding specific technical issues follow.

A. Higher Power in Unlicensed Bands in Areas of Limited Spectrum Use

In Section III.B of the *NPRM,* the Commission examines whether higher power limits for cognitive radios in the ISM bands used for unlicensed operations (902-928 MHz, 2400-2483.5 MHz, 5725-5850 MHz, and 24.0-24.25 GHz) should be applicable in certain circumstances, to improve the usefulness of unlicensed devices in rural areas. Because of the lack of any standardized way to determine whether a unit is in a rural area, the Commission proposes to permit higher power levels in "areas of limited spectrum use" as a proxy, based on the assumption that

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[23] *See also* Cingular/BellSouth IXTemp Comments at 56.

this will correspond generally with rural areas and underserved areas.[24] The way this is implemented is to require devices capable of using higher power to compare the received signal/noise/interference level over a 1.25 MHz bandwidth and determine whether this is less than 30 dB above the thermal noise level for some specified percentage of the device's entire operating frequency range.[25]

Tragedy of the commons. There is no indication in the *NPRM* that the Commission has considered the fact that allowing increased power in areas of limited spectrum use may result in unlicensed devices increasing power in response to other unlicensed devices' increased power, with the net result being that unlicensed devices in such areas will tend toward the maximum permitted power level. The proposed rules do require that the power-enhanced devices must limit their power to the normal level specified by the rules (47 C.F.R. §§ 15.247, 15.249) "when higher power operation is not necessary for reliable communications."[26] But if other unlicensed devices have already escalated power, even higher power may be necessary for reliable communications. Nothing in the proposed rule requires unlicensed devices in areas of limited spectrum use to employ the minimum power level within the rules required for reliable communications.

What "Power" Level Is Affected — Output Power, EIRP, Out-of-Band Power, Peak Power Spectral Density? For spread-spectrum devices, the *NPRM* and its proposed rules would allow use of a "transmitter power" or "power level" six times as high as that permitted under

24 *NPRM* at ¶ 36.

25 *NPRM* at ¶ 40, proposed rule § 15.206(c).

26 *NPRM* at proposed rule § 15.206(c)(iv).

Section 15.247, an increase of about 8 dB.[27] Section 15.247, however, addresses several different power levels, and it is unclear which power levels are intended to be increased.

Section 15.247(b)(i)-(iii) governs "maximum peak output power of the intentional radiator." Section 15.247(b)(iv) governs the EIRP of transmitters using directional antennas. Section 15.247(c) governs the power allowed for out-of-band emissions. Section 15.247(d) governs the permissible peak power spectral density in any given 3 kHz band for digitally modulated signals. The *NPRM* does not indicate which of these would be increased. This is a critical issue because a simple increase in output power would increase power in all of the other power dimensions (apparently including out of band emissions), as well, and thus increase the likelihood of interference. The only increased power level that would lead to more reliable communications in rural areas, without increasing interference to others, while minimizing the need for other unlicensed operators to increase power is the EIRP. The Commission should make clear that any increase in power for unlicensed spread-spectrum devices in areas of limited spectrum use will be limited to changing the system's antenna gain (and thus its EIRP) and should affirmatively state that the output power of the unlicensed device and the level of out-of-band emissions does not increase. Moreover, since the EIRP is increasing due to the raised antenna gain, the Commission may want to specify that the increase in antenna gain is achieved through a decrease in both the azimuth and elevation beamwidths of the radiation pattern. Such specification would preclude the possibility that an antenna with an omni-directional pattern in azimuth could effectively increase its gain through a decrease in the elevation beamwidth only.

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[27] *NPRM* at ¶ 38, proposed rule § 15.206(a). For non-spread-spectrum devices, the existing rules establish field strength limits, rather than power limits; the Commission would allow these devices to have a field strength 2.5 times the limit set in 47 C.F.R. § 15.249. *NPRM* at ¶ 38, proposed rule § 15.206(b). This results in a comparable power increase to that allowed for spread-spectrum devices.

No increase, other than in EIRP, will have a beneficial effect on unlicensed spectrum users. Moreover, increases in EIRP with output power remaining the same will tend to reduce the likelihood of harmful interference to devices not in the intended transmission path. Allowing increases in out-of-band emission or in narrowband digital signals will tend to increase harmful interference to other spectrum users.

Definition of Unused Spectrum. The *NPRM* proposes to define unused spectrum as any spectrum "with a measured aggregate *noise plus interference power* no greater than 30 dB above the calculated thermal noise floor within a measurement bandwidth of 1.25 MHz."[28] This is inconsistent with the proposed rule, which calls for monitoring "*signals* exceeding a monitoring threshold of 30 dB above the thermal noise power within a measurement bandwidth of 1.25 MHz."[29] Is it *signals* or *noise and interference* that must exceed 30 dB above the noise floor? And whose "signals" must be considered? As Cingular and BellSouth commented in the interference temperature proceeding, this implies that the receiver is sophisticated and capable of distinguishing between the intended signal or signals, possibly one or many interfering signals, and thermal and man-made noise.[30] It is unclear, however, how this ability would be mandated within the rules and also how it would be certified as operating correctly. Joint Commenters infer that the Commission intended to require a measurement of the raw power level of the noise, interference, and signal levels received at any given time. The rule would be much clearer if it simply referred to the level of radio frequency power received within the given bandwidth (*i.e.,* the power spectral density).

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[28] *NPRM* at ¶ 44 (emphasis added).

[29] *NPRM* at proposed rule § 15.206(c)(ii) (emphasis added).

[30] Comments of Cingular and BellSouth, *Interference Temperature,* ET Docket 03-237, at 28 (April 5, 2004).

Both the measurement bandwidth of 1.25 MHz and the figure of 30 dB above the noise floor were borrowed from 47 C.F.R. §15.323, which governs isochronous unlicensed PCS devices. However, the Commission never states why it is using these figures, which were set for isochronous devices such as cordless telephones, while the principal usage of the increased power levels is expected to be for WLANs and wireless Internet access,[31] which use asynchronous devices. The unlicensed PCS rules, by contrast, distinguished between asynchronous and isochronous devices. Moreover, the Commission never explains why the figures it borrowed from the unlicensed PCS rules were reasonable figures for determining that a given area has low spectrum usage in the ISM bands. There is no reference to any study or other evidence of spectrum usage versus signal level. There is no explanation for why the Commission chose to use 1.25 MHz as the measurement bandwidth, which is arbitrary, given that the Commission has not specified that as the channel bandwidth.[32] While a 30 dB threshold may be good for usage in the unlicensed bands, it can be disastrous if applied in the licenses bands, *e.g.*, the CMRS service where many users operate at levels closer than 30 dB to the noise floor.

It is unclear from this discussion in the *NPRM,* however, why the value of 30 dB was assumed for these devices. Also, since these devices were developed for isochronous devices, there may be more assurance that the devices could be detected with this type of measurement. If the dominant use for these bands is to be wireless LANs, then the Commission should take greater care to ensure that this threshold will work sufficiently for the various wireless LAN pro-

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[31] *NPRM* at ¶¶ 34-35.

[32] In the isochronous unlicensed PCS rule, the Commission sets 1.25 MHz as both the standard channel spacing and the measurement bandwidth, but allows narrower channels to be used, in which case the same narrower bandwidth must be used for the measurement. *See* 47 C.F.R. § 15.323(a), (c). For asynchronous unlicensed PCS, the rules do not set a specific channel bandwidth or measurement bandwidth; there is a minimum channel bandwidth (500 kHz) and a requirement that the measurement bandwidth be the same as the channel bandwidth used.

tocols and radio standards that exist now and may exist in the future. Also, if the calculation is to be used by unlicensed devices to determine if a segment of licensed spectrum is in use, the calculation must account for the technologies in the licensed band. It is also unclear how the device would account for systems that use bandwidths smaller than 1.25 MHz.

The Commission proposes that units would have to make a determination that some percentage of the spectrum measured fall below the measurement threshold before increased power operation is permitted.[33] It does not, however, propose any specific percentage or suggest how this percentage will be determined. Once a record is compiled on this critical issue, the Commission will need to set forth a specific proposal in a further notice of proposed rulemaking before proceeding to adopt rules. Joint Commenters cannot comment on a proposal that lacks the requisite substance and rationale.

Antenna Type. The *NPRM* asks for comment on the type of antenna to be used for the measurement.[34] This reveals a problem in the approach of using DFS. Depending on the antenna pattern and the locations of the other transmitters and receivers, there is no way for an unlicensed device (assumed in this case to be TDD) to know if it is interfering with another device. If a directional antenna is used, then the main beam of the antenna must be pointed towards the source of the radiated signal to ensure the power level can be measured correctly. Without using the main beam of the antenna or knowing the direction of arrival, the unlicensed device cannot know its own antenna gain in the receiving direction. The only way for this type of operation to work is when the other transmitters and receivers are located in the same location (*i.e.,*

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33 *NPRM* at ¶ 44, proposed rule § 15.206(c)(3).

34 *NPRM* at ¶ 44.

the monostatic radar situation described for 5 GHz DFS) or to use sophisticated antenna arrays to determine the angle of arrival.

RF Safety Considerations. The NPRM raises the issue of RF safety.[35] There could be problems for specific absorption rate (SAR) if unlicensed devices — especially end-user devices — are allowed to operate at elevated power levels.

Coexistence with Low Power Devices. The NPRM asks how devices operating at the increased power level would coexist with low power devices, acknowledging that "allowing some devices in a band to operate with higher power could block the use of lower power devices."[36] If the Commission cannot answer this question, a proposal to increase power levels is not warranted. It is necessary to determine how to keep high-power devices from simply blasting out more power or exhibiting other poor behavior before moving forward with rules. Obviously, there should be some requirement to re-sense the spectrum usage at appropriate intervals.

B. Mesh Networks

In paragraphs 77-80 of the *NPRM,* the Commission seeks comment on a variety of issues concerning "mesh networks," including the impact of mesh networks on the aggregate interference to licensed users. To the extent mesh networks are used to relay end-user traffic to the Internet indirectly via a series of informal repeaters instead of linking to a wired Internet connection, they result in higher channel occupancy because multiple devices will need to carry the same traffic. This inevitably will increase the background noise level in-band over what would exist if a single access point were connecting to the Internet. The Commission should undertake

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35 *NPRM* at ¶ 45.

36 *NPRM* at ¶ 46.

a study of the noise and interference level caused by a mesh of an unknown number ("N") of devices versus a single higher-powered link (within the limits of Part 15).

More fundamentally, it is unclear why the Commission is asking how much interference *licensed* users will experience from mesh networks, assuming such networks are operating within the existing limits set by Part 15. Part 15 devices are supposed to avoid causing harmful interference to licensed services regardless of whether they are acting in a mesh or not.

At a minimum, if the Commission proceeds with its apparent intention to allow cognitive Part 15 devices to access licensed spectrum, it has an obligation to examine the cumulative interference that will result to licensed operations not only from an individual device, but also from a mass of devices arrayed throughout the licensee's service area at varied spacing. Such devices could be used in every home or office, like cordless phones or WLAN devices today. The issue is the level of interference from a ubiquitous array of Part 15 devices at the permitted power level, not whether these devices are acting as a mesh network.

C. Rule Changes for Software Defined Radio

As the *NPRM* observes, just over two years ago the Commission adopted its rules for software defined radio.[37] The Commission also notes that no company has yet submitted products for approval under the new rules.[38] The fact that there have been no products submitted under the current rules might be an artifact of the Commission's current rules or it might be a function of the product development life cycle of software defined radios in the marketplace.

Submission of Radio Software. The Commission has proposed deleting the current requirement that the manufacturer supply source code for radio software upon FCC request, and

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[37] *Software Defined Radio,* ET Docket 00-47, *First Report and Order,* 16 F.C.C.R. 17373 (2001), *cited in NPRM* at ¶ 82 & n.99, 84.

[38] *NPRM* at ¶ 84.

instead requiring only that the manufacturer supply a "high level description of the radio software and flow diagram of how it works" upon FCC request.[39] In its reply comments in the SDR proceeding, Cingular argued that the approval process should include the actual submission of the software.[40] One purpose for the requirement to submit the source code for devices that were declared to be SDRs was to ensure that certain operational characteristics of the device were maintained within the scope of the authorization and that presumably the transmitting device could not be misappropriated for improper operation. Joint Commenters continue to support this goal. Should the Commission decide to delete this current requirement, it must insure that software changes affecting the RF emission characteristics of a device do not cause interference to licensed operators.

Requirements for Software Defined Radio. The Commission has asked a variety of questions concerning regulatory requirements for software defined radio.[41] The Commission's, and even the industry's, view of what constitutes software defined radio is very broad. Regardless of whether a software defined transmitting device is declared an SDR under the Commission's current rules, or is merely used as an effective means to construct a radio device, it is prudent to require some basic criteria be imposed on transmitting devices that are constructed using the concepts of software defined radio. Software defined radio brings a degree of flexibility; such flexibility should have an attendant obligation to ensure that the flexibility is not misapplied. Principally, these criteria should address the security methods used to protect the radios against unapproved software and to protect software-defined, remotely-programmable transmit-

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39 *NPRM* at ¶ 86.

40 Reply Comments of Cingular Wireless LLC, *Software Defined Radio,* ET Docket 00-47, at 5 (May 18, 2001).

41 *See NPRM* at ¶ 88.

ting devices from being inappropriately and indiscriminately modified to operate in an unauthorized manner.

Such regulations should apply to all radio hardware that meets the definition of software defined radio *and additionally is capable of being remotely programmed*, whether or not it is marketed as such. The concept of *"additionally is capable of being remotely programmed"* is a critical distinguishing factor. A software defined radio could be utilized by a manufacturer as a proprietary means of building a radio such that the flexibility of the SDR is used internally in the manufacturing process and is never available to or even necessarily revealed outside the factory. In such a case, even though SDR is being utilized, it is indistinguishable from non-SDR radio implementations – the flexibility and adaptability post-manufacture are not open or available.

Contrast this to the case of a transmitting device that uses software defined radio techniques and is designed for some level of flexibility, reconfigurability, adaptability or evolvability in a post-manufacture environment. This type radio device, to use an example from the commercial wireless marketplace, would be designed to be able to be remotely diagnosed and maintained (*e.g.,* software "bug" fixes), to have updates and enhancements to the radio downloaded over the air to the device, and to be, within a range of parameters, remotely adjusted in its operation. Such a device for practical commercial deployment by an operator requires a high degree of security and integrity to ensure that its operations are not compromised, and to promote proper controllable and predictable operation. Business will demand that a high level of attention be given to such security. This software defined radio embodies the concept of *"additionally is capable of being remotely programmed"*. Such flexibility and remote programmability must bear a responsibility for ensuring that 1) security methods are used to protect the radios against unapproved or incompatible software and 2) protection is incorporated to preclude software defined remotely programmable transmitting devices from being inappropriately and indiscriminately modified to operate in an unauthorized manner. This responsibility should not be exempt from Commission consideration merely because the manufacturer chooses not to highlight or divulge the reprogrammability of the device or because a particular deployment of such a remotely reprogrammable device chooses to not utilize the inherent remote programming capability. The Commission must ensure that software defined radio devices, as originally configured or subsequently reconfigured, do not cause additional interference, especially to licensed services. As in the past, the requirement that the unlicensed device must cease operation if it is interfering with licensed services must continue to be enforced and upheld even if they are constructed using software defined radio techniques.

Consequently, Joint Commenters believe that it would be appropriate for the Commission to apply the requirement of Section 2.932(e) of the Commission's rules to "take steps to ensure that only software that has been approved with a software defined radio can be loaded into such a radio" to all software defined remotely programmable transmitting devices whether they are "declared" as SDRs or not. But, in keeping with the prevailing view, the Commission should not mandate the specific security methods used to meet this requirement.

The industry, including manufacturers and operators, has significant incentive to develop the necessary security mechanisms to prevent misuse of software defined radios. These developments have and continue to occur in specific proprietary and innovative ways and also publicly in the various forums and industry standards groups around the world.

It is prudent to require that manufacturers requesting authorization for transmitting devices that incorporate software defined remotely programmable technology and/or capabilities certify to the Commission that the appropriate security mechanisms are in place. The Commission need not define these mechanisms nor would this requirement for a certification statement alter the current ability for a manufacturer to declare a device to be an SDR if it wished to take advantage of the Commission's streamlined provisions associated with declared SDRs.

To further promote the proliferation of software defined radio as a radio implementation technique, the Commission should consider amending the existing rules to allow the use of a Telecommunication Certification Body ("TCB") as a means of authorizing software defined radios in two cases — first, where the device is "declared" as an SDR and second, where software defined radio is merely used as an implementation technique in a software definable and remotely programmable transmitting device. These two cases cover the range for software-defined radio from a Commission and industry perspective. In many cases manufacturers have existing arrangements to use TCBs for non-SDR based radios. Extending TCB availability to SDR based radios would be cost effective and practical. The contractual obligation and confidentially provisions between a TCB and a manufacturer address the concerns associated with revealing trade secrets of software defined radio implementations and reduces the potential for weakening the needed security mechanisms through public disclosure.

The *NPRM* asks whether the software defined radio rules should apply to individual transmitter modules, as well as to complete transmitting systems.[42] The answer, clearly, is yes. Absent such a requirement, rules applicable to complete transmitting systems will be routinely evaded by dividing transmitters into separate, exempt, modules. Any "module" of a transmitter that can affect its operation and potential for interference should be subject to the rules.

Automatic Frequency Selection Based on Country. In paragraphs 95-98, the *NPRM* asks whether and how devices should determine the country in which it is being operated in or-

[42] *NPRM* at ¶ 89.

der to select frequencies permitted in that country. The short answer is that there is no *reliable* means for a device to determine the country in which it is being operated. GPS is no answer, given that many devices will be used indoors or in locations where GPS signals are unavailable. Identification of the country based on interaction with other devices seems unlikely to be accurate. For example, a device contained on a PCMCIA card plugged into a laptop might query the computer for information about the time zone and area code to identify the country, but the user may leave this information unchanged when taking the laptop into a different country. A European user, for example, might leave a computer programmed with his or her home country's identifying information when visiting the United States, and the wireless card would then assume that it is still in Europe and use spectrum according to European rules.

Earlier in the *NPRM,* the Commission acknowledged that there is no reliable way for a device to know that it is in a rural area. There is likewise no reliable way for a unit to determine whether it is in the United States. Moreover, even if such a rule were adopted, it would remain difficult to enforce compliance. It would be, as now, relatively straightforward to buy devices in another country and bring them into the United States and use them illegally.

Pre-Certification Testing Requirements. The *NPRM* proposes a number of pre-certification tests and seeks comments on other testing requirements in paragraphs 101-102. Joint Commenters suggest that the testing should include both broadband sources and also narrowband sources and the equipment under test must alter its behavior correctly in both cases. With regard to what organization should develop the tests, it may be preferable to have an industry body such as ANSI or the IEEE do this work. However, the Commission, as an unbiased regulatory agency, must exercise supervisory review to ensure that the tests do not favor one technology over another and to prevent the omission of tests merely because equipment manufacturers find them unpopular or hard to implement.

Rules for Listen-Before-Talk systems. In paragraph 105, the *NPRM* proposes several tests that may be applied to listen-before-talk systems. None of these tests, however, would allow for the detection of mobile receivers in systems that utilize FDD, assuming the base station frequency is the one being used, and *vice versa*. Furthermore, the tests do not account for the dynamic nature of the radio links in CMRS networks such as cellular and PCS. In addition, it is unclear how the device could detect RF signals that are below the noise floor of the measurement receiver, given that the cyclostationary methods discussed earlier in the *NPRM* require listening periods that are too long to be useful with respect to CMRS networks. These difficulties may be further compounded by differences in bandwidth between the licensed network's signal, the unlicensed device's signal, and the measurement receiver. These issues will not be easy to resolve and the Commission must address them before moving forward with new rules.

Geolocation Tests. Paragraph 106 of the *NPRM* proposes tests for devices that would be expected to determine their location. These tests presume that "GPS or some other method" would be capable of determining a device's location. GPS clearly is not a dependable method for determining the location of a device that is not used primarily outdoors in an open area — and is particularly unsuitable for devices that will almost always be used indoors, like the vast majority of wireless network devices and cordless phones. The added cost of including a GPS receiver would also be a factor. The Commission does not identify any "other method" that would work any better. Moreover, the *NPRM* indicates that such devices would access a database to determine what frequencies are permissible once the location is determined. It is unclear what database could possibly be used. Any database contained in the unit would be out of date as soon as it is programmed. Moreover, there are no reliable, readily accessible databases online containing the information required. The Commission's own online databases require the use of a variety of different interfaces and extensive queries to obtain even a fraction of the information needed, and much of the information that would be necessary is not available even from the Commission. For example, the Commission does not maintain a database of what frequencies within the CMRS bands are used in particular locations or with particular technologies. It is unclear whether a database such as the one referred to in paragraph 106 could be compiled, how long it would take, how it would be kept continually updated, or who would pay the expense. Moreover, in numerous services, geographic area licensing is used, and as a result there is no publicly accessible record of the exact location of licensed base station transmitters and receivers.[43] Also, even if such a database existed it would still not contain the locations of licensed mobile devices, which can be assumed to be present at virtually any location.

Heteromorphic waveforms. In paragraph 107, the *NPRM* acknowledges that cognitive radios may use "new or novel formats" for transmissions, including splitting a transmission among multiple noncontiguous channels. Such "heteromorphic waveforms" had been discussed earlier in the *NPRM* as a way for cognitive radios to take advantage of gaps in spectrum usage.[44] Accordingly, the *NPRM* seeks comment on how power and other measurements should be made with respect to such waveforms. Joint Commenters submit that the measurements should be defined over each individual range of frequencies (as well as over the frequencies with which they are paired, in the event the frequencies are used for FDD by licensed operators). This is essentially a problem of doing the multiplexing and de-multiplexing of the information over various

43 The move toward geographic licensing has given licensees greater flexibility. However, geographic licensing makes this type of database lookup more difficult, if not impossible.

44 *See NPRM* at ¶ 26.

radio frequencies. The Commission must ensure that the power, EIRP, and out of band emission limits are met, no matter what waveform or waveforms are used.

CONCLUSION

For the foregoing reasons, Cingular and BellSouth support the use of cognitive radios, where warranted, within licensees' networks, within spectrum separately allocated for unlicensed usage, and as part of a negotiated secondary market arrangement for voluntary unlicensed access to licensed spectrum. Cingular and BellSouth oppose mandated sharing of licensed spectrum with unlicensed devices based on the use of cognitive radio technology.

Respectfully submitted,

CINGULAR WIRELESS LLC

By: /s/ David G. Richards /ms
J. R. Carbonell
Carol L. Tacker
David G. Richards
5565 Glenridge Connector
Suite 1700
Atlanta, GA 30342
(404) 236-5543

Its Attorneys

BELLSOUTH CORPORATION

By: /s/ Charles P. Featherstun /ms
James G. Harralson
Charles P. Featherstun
1155 Peachtree St., N.E.
Suite 1800
Atlanta, GA 30309
(404) 249-3855

Its Attorneys

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